

CLAIMS

1. A susceptometer for non-invasive determination of iron concentration in a body, by detecting the magnetic flux variation produced by the body,
5 characterized in that it comprises:

- a heat insulating case (16), containing a support structure, which is made of a non-magnetic and electrically insulating material, and operationally kept substantially at room temperature, and which
10 defines a screening region (8, 10);

- an alternating magnetic field source (2), supported by said structure and able to generate a magnetic field in said screening region;

- at least two magnetic field sensors (4, 6),
15 supported by said structure and disposed in front of said field source (2);

- means (12, 14) for introducing the body to be screened in the screening region (8, 10) defined by said field source (2) and at least one of said at least
20 two sensors (4, 6);

- temperature control means, for stabilizing temperature inside said case, at least during measurement, in such a manner as to limit relative variation to a predetermined maximum value, so that
25 thermal expansion of the support structure and the associated field source (2) and sensors (4, 6) are substantially ininfluent on the variations in the magnetic field flux linked with the sensors (4, 6); and

- means for processing electric signals indicative
30 of the variation in the magnetic flux linked with the



sensor, which variation is caused by the presence of the body being screened, in the screening region.

2. A susceptometer as claimed in claim 1, characterized in that it has a first (4) and a second
5 (6) sensors, which are arranged on the support structure in symmetrical positions with respect to said field source (2) and wherein a screening region (8, 10) is defined between said field source (2) and each sensor (4, 6).

10 3. A susceptometer as claimed in one or more of the preceding claims, characterized in that it further includes at least two additional sensors (20, 22), which are supported by said structure and arranged in the proximity of the field source (2) in front of it,
15 so that the variation of the magnetic field flux linked with said additional sensors, which is caused by the presence of a body in this screening region, is substantially the effect of the magnetic properties of the outermost parts of said body.

20 4. A susceptometer as claimed in one or more of the preceding claims 1 to 3, characterized in that it has a second heat insulating case (18), which defines a temperature controlled environment in it.

25 5. A susceptometer as claimed in claim 4, characterized in that said means for introducing the body to be screened include a first (12) and a second (14) tunnels, made of a non-magnetic insulating material, and disposed in the screening regions (8, 10) respectively, with an introduction aperture outside the
30 walls of said first (12) and second (18) cases.

6. A susceptometer as claimed in one or more of the preceding claims, characterized in that said temperature control means comprise a plurality of heating/cooling members, associated to the support structure, temperature sensing means for detecting temperature near said heating/cooling means and means for adjusting the temperature of said heating/cooling means, as a function of the temperature measured by said sensors.

7. A susceptometer as claimed in claim 6, characterized in that said heating/cooling means have weak magnetic properties.

8. A susceptometer as claimed in one or more of the preceding claims 1 to 5, characterized in that said temperature control means include heating/cooling means associated to the walls of said first case (16) and/or said second case (18).

9. A susceptometer as claimed in claim 5, characterized in that said temperature control means include heating/cooling means associated to the walls of said first (12) and second (14) tunnels.

10. A susceptometer as claimed in one or more of the preceding claims 1 to 9, characterized in that said processing means include a lock-in amplifier, which is able to read the signal produced by said sensors, wherein the signal read by said lock-in amplifier is null if no sample is inserted in said screening region.

11. A susceptometer as claimed in claim 10, characterized in that the processing means include a computer, which is arranged to acquire the output

signal of said lock-in amplifier in synchronism with the introduction and extraction of the sample from the screening region.

12. A susceptometer as claimed in one or more of the preceding claims, characterized in that the first case (16, 18; 30, 31) and the second case define a liquid-tight gap therebetween, through which a temperature-controlled diathermic fluid flows, to stabilize the temperature of the susceptometer structure.

13. A susceptometer as claimed in one or more of the preceding claims, characterized in that it has a support structure for the magnetic field source/s (2, 2' and small magnet) and the pick-ups (4, 4'; 6, 6'), including an upright (21), wherefrom three cantilevers (22) project at different heights and in substantially aligned positions to support the magnetic field source/s (2, 2' and small magnet) and the pick-up/s (4, 4'; 6, 6') respectively.

14. A susceptometer as claimed in claim 13, characterized in that the upright (21) and/or the cantilevers (22) are provided as tubular or box-like elements, like panels, and may be removably fastened together by locking and/or centering means.

15. A susceptometer as claimed in claim 12 or 13, characterized in that the cantilevers (22) are joined to the upright by means of extensions of their vertical side walls, which have the form of fastening tabs, abutting against the corresponding side walls of the upright (21) and secured thereto by means of fast pins

and dowels (23, 24).

16. A susceptometer as claimed in one or more of the preceding claims 12 to 15, characterized in that the cantilevers (22) have cavities for receiving the
5 pick-up/s (4, 4'; 6, 6') and the magnetic field source/s (2, 2' and small magnet) respectively, which cavities are formed within the thickness of said cantilevers.

17. A susceptometer as claimed in one or more of
10 the preceding claims 12 to 16, characterized in that the pick-up/s and the magnetic field source/s are secured inside the thickness of the cantilevers (22) by dowels (222) and fast pins (322).

18. A susceptometer as claimed in one or more of
15 the preceding claims 12 to 17, characterized in that the lower end upon which the upright rests, is connected to a base plate by means of trapezoidal reinforcement plates (25), which are fastened to said base (26) and to the side walls of the upright (21)

20 19. A susceptometer as claimed in one or more of the preceding claims 12 to 18, characterized in that the support structure (20) with the pick-ups (4, 4'; 6, 6') and with the magnetic field source/s (2, 2' and small magnet) are accommodated in a first inner shell
25 (30), which has a cavity (130) for housing the upright (21) which cavity communicates with three cavities for housing the cantilevers (22), the lower portion of the first cavity (130) being widened to form a trapezium which corresponds to the trapezoid base (25) of the
30 support structure (20).

20. A susceptometer as claimed in claim 19, characterized in that the assembly composed of the support structure (20) with the pick-ups (4, 4'; 6, 6') and with the magnetic field source/s (2, 2' and small magnet) and its first inner shell (30) are accommodated in a second outer shell (31), whose shape corresponds to that of the first inner shell (30), and whose size is larger to form a sealable gap, through which a diathermic fluid may flow for temperature stabilization purposes.

21. A susceptometer as claimed in one of claims 19 or 20, characterized in that the first inner shell has two tubular supporting beams (32) along the side walls, at the trapezoidal widened base.

22. A susceptometer as claimed in claim 21, characterized in that the two tubular support beams (32) also act as inlets and outlets for the diathermic fluid flowing in the gap between the inner shell (30) and the outer shell (31).

23. A susceptometer as claimed in one or more of the preceding claims 12 to 22, characterized in that it is provided in combination with a patient table, a stretcher, or the like (40), whose patient supporting surface (43) is supported in such a manner as to be able to move vertically between the two operating positions in which the body to be screened is introduced, between the cantilever that supports the magnets (2, 2') and the cantilever of upper pick-ups (4, 4') and between the cantilever that supports the magnets (2, 2') and the cantilever (22) of lower pick-

ups (6, 6') respectively.

24. A susceptometer as claimed in claim 23, characterized in that the patient supporting surface has a cavity for accommodating the cantilever (22) that supports the lower pick-up/s (6, 6') and/or the cantilever (22) that supports the magnetic field source/s (2, 2').

25. A susceptometer as claimed in claim 23 or 24, characterized in that the patient table or stretcher (40) has a base (41) that runs on rails.

26. A susceptometer as claimed in one or more of claims 23 to 25, characterized in that the body supporting surface (43) may be lifted or lowered with respect to the base (41), thanks to a jointed arm lifting system (42) and removable position lock means.

27. A susceptometer as claimed in one or more of the preceding claims, characterized in that it has three magnetic field sources (2, 2' and small magnet), each being able to generate different magnetic field flux distributions.

28. A susceptometer as claimed in claim 27, characterized in that two pick-ups (4, 4'; 6, 6') are provided on each side of the magnetic field sources (2, 2'), each being dimensionally adapted to the volume permeated by the magnetic flux of the corresponding magnetic field source (2, 2').

29. A susceptometer as claimed in one or more of the preceding claims 28 to 28, characterized in that it has two magnetic field sources (2, 2'), formed by annular circular coils, which have different diameters,

one being contained in the other, and are coaxial to each other and to the two pick-ups (4, 4'; 6, 6'), the latter being themselves provided as coils, one in the other and coaxial to each other, the size of concentric coils (4, 4'; 6, 6') being adapted to the size of the corresponding magnetic field source (2, 2').

30. A susceptometer as claimed in one or more of the preceding claims, characterized in that an additional magnetic field source is associated to each pick-up or pick-up pair (4, 4'; 6, 6').

31. A susceptometer as claimed in claim 30, characterized in that said magnetic field source has an annular shape and is mounted coaxially inside the smaller pick-up of each pick-up pair (4, 4'; 6, 6').

32. A method for measuring the content of magnetic material, particularly metals, especially iron, in a body, by a susceptometric measurement of field variations caused by the presence of said screened body in the magnetic flux, which includes the steps of:

- a) generating a measuring magnetic field;
- b) measuring the magnetic field that permeates the screened body;
- c) measuring the magnetic field with no body in it, for generating a reference signal;
- d) comparing the reference signal with the measuring signal, obtained with a body in the magnetic flux; the magnetic material build-up in the screened body is derived from the difference between said two signals.

characterized in that the reference signal and the



actual body signal are measured at the same time, by generating a magnetic field that is symmetric with respect to a magnetic field source, the reference signal being measured on one side of the magnetic field source and the actual body signal being measured on the opposite side of the magnetic field source, whereas the build up of magnetic material in the body being screened is derived from the difference between said two signals.

10 33. A method as claimed in claim 32, characterized in that said measurements are also made by inverting the position of the screened body with respect to the magnetic field source.

15 34. A method as claimed in claim 32 or 33, characterized in that several measurements are made for each measuring configuration.

20 35. A method as claimed in one or more of the preceding claims 32 to 34, characterized in that the structure for supporting the magnetic field source and the field measuring means is kept at a constant temperature, during measuring operations.

25 36. A method as claimed in one or more of the preceding claims 32 to 35, characterized in that magnetic fields are generated for each measurement, which have a different spatial extension, and permeate wider or narrower portions of the screened body respectively.

30 37. A method as claimed in claim 36, characterized in that said magnetic fields having different spatial extensions are coaxial to each other.

38. A method as claimed in claim 36 or 37, characterized in that all measurements of the process are used to determine iron overload in the human body and the distribution thereof.

5 39. A method as claimed in one or more of the preceding claims 32 to 38, for determining the amount of iron stores in the liver.

10 40. A method as claimed in claim 39, for in vivo determination of the amount of iron stores in the liver.

41. A method as claimed in claim 40, for determination of the amount of iron stores in the liver of thalassemic patients.